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FIRST RESULTS IN ON MAGNETOHYDRODYNAMICS PROJECT

Amstelveen ENERGIE SPECTRUM in Dutch Sep 80 p 203

[Text] With the appearance of the report 'Project data for the study of a coal-fired 1,200 MWth open-cycle MHD/steam plant,' the first phase of a number of Dutch MHD studies was concluded some months ago. These studies are carried out by some Dutch industries with subsidies from the Ministry of Economic Affairs. The activities are coordinated by the Energy Research Projects Office of the ECN, which, otherwise, is also actively participating in the studies.

During the second stage of the project, a number of enterprises carry out project studies on components which are essential to an MHD steam system, such as burners, the MHD generator, the superconductive magnet and the combustion air preheaters. Participating enterprises are, so far, VMF-Stork, Holec, and ESTEL.

The TH Eindhoven and the National Air and Space Laboratory, which, like the ECN, from the start have been involved in the industrial efforts to obtain support from the Dutch authorities for a Dutch MHD project, play an important advisory role at this stage.

The results of the study, which must be ready about 1 November, will be used in evaluating the question in which way to continue the development of MHD systems. For this purpose, among other things, the results of this study will be compared with those of similar studies of the coal-fired STEG system and the potassium/steam system, which are carried out by the KEMA and the TNO-Neratoom group, respectively. For those who are interested, the above-mentioned report can be obtained from BEOP, p/a ECN, P.O.BOX 1, 1755 ZG Petten, telephone 02246-6262.

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PRESSURIZED FLUIDIZED-BED COMBUSTION: POSSIBLE USE STUDIED

Amstelveen ENERGIESPECTRUM in Dutch Sep 80 pp 205-213

[Article by J. B. Fortuin and F. Stab]

[Text] In the first part of this article, published in ENERGIESPECTRUM of June 1980, a survey was given of the properties, application possibilities and future expectations of fluidized bed combustion at atmospheric pressure of coal in the Netherlands.

In the said article, the advantages were pointed out of this otherwise already long known technique of bringing about an intensive contact between a layer of material consisting of whirling particles and a gas flowing through it.

These advantages are made even stronger if the pressure in the combustion chamber is higher than the atmospheric pressure (the so-called Pressurized Fluidized Bed Combustor). This applies especially to the specific heat generation (i.e. the capacity generated per volume unit) and to the heat transfer in the pipes fitted in the bed for bed cooling. The possibility of trapping the sulphur by adding limestone or dolomite exists just as in the case of the AFBC (atmospheric fluidized bed combustion). By increasing the pressure in the fluidized bed combustion, a relatively smaller production of nitric oxides (NO_x) can be attained.

In principle, the use of PFBC (pressurized fluidized bed combustion) thus offers the possibility of producing the same amount of flue gas of the same temperature and composition in smaller and thus perhaps also less costly equipment as in a bigger AFBC boiler.

The problems are, however:

1. Obtaining the needed combustion air under pressure, for which costly compressors are necessary, which, moreover, need much high-value (for example, electrical) energy for operation.

2. The use of the mechanical energy of the pressurized hot gas of 800 to 900°C emitted from the combustion chamber.

In this connection, the attention is drawn to the use of a gas turbine, which, in general, consists of the following:

1. A compressor to compress air to a certain pressure.

2. A combustion chamber to increase the temperature of the work medium (air-flue gas) to 750-1,100°C. by means of combustion of fossil fuel.

3. An expansion turbine in which the current of gas emanating from the combustion chamber(s) expands to atmospheric pressure and by means of which the energy needed for the air compression is supplied (approximately 2/3) as well as the energy which becomes available to the outside (approximately 1/3).

In order to use the PFBC reator as coal-fired combustion chamber, it is significant to combine PFBC with a gas turbine. It should be noted in this context that the industrial gas turbine in the course of the last 20 years has been developed into a reliable prime mover, and that the combination of a gas turbine and a subsequent steam cycle (STEG or combined cycle installation) makes possible high conversion yields (at the moment up to 46 percent!). The gas turbine, moreover, lends itself excellently to use in so-called heat-power plants, and the penetration in industrial as well as town heating projects is taking place at an accelerated rate.

The combustion of coal in a combustion chamber based on the principle of fluidized bed combustion under pressure now offers the possibility to operate a gas turbine with coal as fuel and, at the same time, preventing the sulphur dioxide emission from getting above the permissible level, while, at the same time, the emission of NO_x is reduced when compared with conventional combustion.

For this reason, and in order to make the principle applicable to the production of electricity and heat, test installations are today in preparation or in operation in different countries, notably in the United States, the Federal Republic of Germany and the United Kingdom.

In the following, the present state of the technology and the future expectations, especially with regard to the Dutch energy economy, will be discussed in greater detail.

Energy Generation by Means of Fluidized Bed Combustion Under Pressure

As mentioned in the introduction, the use of a gas turbine is attractive in connection with the use of the PFBC principle. Figure 1 shows a diagrammatic sketch of a PFBC-STEG installation. In current gas turbines, air is compressed to a pressure of 4 to 12 bar. The compressor may be integrated with a gas expansion turbine or be carried out as a separate air compressor.

In the PFBC chamber, the air is added as combustion air and oxidizes the fuel (coal) to combustion gas, usually at a temperature of approximately 850°C. The bed is cooled, and this can take place by means of water/air, as shown schemmatically in figure 1 or by means of air which is then heated by means of heat escaped from the bed between compressor and gas expansion turbine. The steam can be generated in the PFBC reactor as well as in the residual heat boiler connected after the gas turbine.

It is also possible to cool the bed exclusively by means of superheated steam in the boiler pipes functioning as heat exchanger. The various possibilities of connection, according to figures 1, 2, and 3, will be dealt with in greater detail later on.

In all cases, a very careful choice of material for the heat-exchanging surface to be placed in the bed is necessary in connection with the very high heat current density toward the pipes, irrespective of the relatively low combustor temperature. The problem is here that the material of the pipes must be resistant to erosion and corrosion by substances present in the bed, such as potassium and sodium. Another very important problem is the purification of the hot flue gas before it enters the gas expansion turbine. For this, three different techniques are, in principle, available, which certainly have not yet been sufficiently developed for this use and in which connection much research and development work will still have to be carried out. Combinations of the three methods may perhaps also be used, viz.

1. In cyclones connected in series;

2. Electrostatic filters;

3. Granular bed filters, porous layer filters or filters woven of heat resistant metal wiring.

As the temperature of the flue gas after the PFBC reactor is limited in connection with the ash melting point and must continuously be below 900°C, the most modern gas turbines, which have been designed for temperatures of 1000°C. and above, cannot be used in their original design. They may, however, sometimes be used at a lower temperature and thus at a lower outward capacity than they were designed for. Another possibility would be to heat further the gases emitted from the combustion chamber, which, at the burning with a great excess of air, still contain sufficient oxygen, by means of additional firing with gas or oil to the desired higher temperature.

As regards the subject of the steam cycle, numberous variations are possible, and especially heat power operation is also possible. In the case of heat power operation, the desired ratio electricity/steam (heat) may be chosen within very wide limits.

As regards the subject of the installation, special attention should be given to the dynamic conduct and to the adjustment, Obtaining a good adjustment is a problem for which solutions still have to be found. For the production exclusively of electricity, there is a certain preference for the air-cooled fluidized bed, whereby the emphasis of the complete installation is less on the steam cycle side than in the case of a water/steam cooled bed. As the maximum yield of the steam cycle amounts to approximately 40 percent, an increasing share of the steam cycle reduces the combined cycle yield.

Experience With Similar Installations

Fluidized bed installations with gas expansion turbine where not fired with coal have been used in the oil industry for more than 25 years and also, for example, in the direct reduction of iron ore. Especially in the catalytic cracker installations frequently used in oil refineries with a fluidized bed regenerator for the burning of petroleum cokes of the catalyst particles, much experience has been gained with gas purification by means of cyclones as well as with construction and operation of the gas expansion turbines which convert the available pressure energy in the purified combustion gases to ash capacity. This capacity is mostly added directly to the air compressor; the excess capacity is often used for generation of electricity.

In certain cases, the dust concentration at the entry into the first cyclone is 3,000,000 ppm, a multiple of the concentration which can be expected in the case of the PFBC. By using three steps of cyclones, this concentration can be reduced to 120-160 ppm (1, 2), and can thus be reduced by a factor of 20,000! It is in this connection desirable to remove all particles >12 u, 99 percent of the particles >10 u, and 91 percent of the particles >5 u. This degree of purification has been amply attained through years of practical experience.

Figure 4 shows a model of a catalytic cracker installation of a refinery in Austria and shows the high temperature/high pressure gas pipes to the regenerator, the various cyclones, and the gas expansion turbine, which operates an electrogenerator.

By taking the required constructive and technical measures, as far as the materials are concerned, the lifetime of vulnerable turbine parts can be increased considerably (4), for example of the first turbine blades to 40,000 hours. The temperature of the gas at the entry of the turbine is lower in the case of a catalytic cracker installation than in the case of PFBC, viz. a maximum of 750°C., and, in general, between 600°C and 700°C., but it nevertheless appears that the danger of erosion can be limited effectively.

It seems very important in the further development of PFBC gas turbine installations to make use of all the experience gained in connection with FCC installations (FCC - Fluid Cat. Cracker) on the subject and the construction of gas purification as well as the gas expansion turbine.

Conceptions of PFBC Systems

Of the many possible combinations, the following three in particular deserve special attention (6):

1. STEG (Steam and Gas Turbine) installation with water/steam cooled fluidized bed reactor, whether or not with intermediate superheating (figure 1);
2. STEG installation with air-cooled fluidized bed combustion chamber combined with steam cycle (figure 2);
3. Steam cycle with steam boiler under increased pressure (figure 3).

System 1

In the case of bigger PFBC units of this conception, one can readily use intermediate superheating. An example is given in (6) of a big PFBC electricity plant with intermediate superheating; the generators have a total capacity of 369 MWe, 75 MWe of which in the gas turbine and 294 MWe in the steam turbine, with a yield of 39.1 percent.

In the bed itself, approximately 2/3 of the generated heat is carried off toward the steam cycle if a fairly low air excess factor of, for example, 1.2 is used; consequently, the yield cannot be much higher than the value mentioned of 39 percent. The emphasis of such a STEG installation has been strongly shifted toward the steam side, as far as a natural gas-fired STEG installation is concerned. This type of installation is very much suited for heat/power coupling for industrial use or for town heating as a high heat/power ratio is attainable.

System 2

In an air-cooled bed, for example 2/3 of the air compressed by the compressor will be used to absorb the bed heat. This air current is heated, for example, from 250°C to 725°C. The rest of the air current is used as fluidization and combustion air and, after purification, for example in three cyclone steps, mixed with the air heated in the system of pipes, whereby a temperature of about 775°C. will occur at entry into the expansion turbine.

After passing through the turbine, the flue gases cool further off in a residual heat boiler to a stack temperature of about 150°C. In this case, the emphasis of the STEG installation is again strongly in the direction of the Brayton cycle (gas turbine cycle).

The yield cannot, however, be as high as that of the most modern natural-gas fired installations, as a result of the relatively low gas turbine temperature. It could, at a maximum, amount to approximately 38 percent. The investment costs, however, are relatively low, as the gas turbine provides approximately 2/3 of the total capacity. It is, moreover, an advantage that the material which still remains in the flue gases after the gas purification is rarefied by being mixed with clean air. On the other hand, there is the constructive disadvantage of the thermally very highly loaded and thus expensive pipes which are placed in the bed.

System 3

The third possibility consists of use of the PFBC boiler as 'charged' steam boiler, that is to say: as a steam boiler where, as far as the gas is concerned, an increased pressure prevails in the boiler. This type of boiler has already been known for a very long time, such as the Velox boiler which existed already before WWII and which is used by BBC and Sulzer. The expansion work in a PFBC cycle is here completely used for compressing the sucked-in fluidization air to the desired pressure of, for example, 10 bar by means of a gas turbine which gives off no outside energy. As the gas expansion turbine need not give off any energy to the outside, the gas entry temperature can be relatively low, viz. 600°C. to 700°C.

The advantage of this PFBC use, where electricity is generated exclusively by means of steam, lies primarily in the compact design, the lesser requirements with regard to gas purification and the expansion turbine in connection with a lower temperature and the high heat transfer and sulphur retention compared to conventional steam boiler systems. Here, there is, furthermore, not the complication of two separate generators. Since the gas turbine temperature in the gas expansion turbine is kept relatively low, the enthalpy still present in the gas after expansion will primarily be used for feedwater heating. The yield of the cycle can amount to 36-38 percent.

The three combinations mentioned show, as far as the yield is concerned, no great differences. The water-cooled fluidized bed system 1 (with intermediate superheating) appears to provide the highest yield. This system, moreover, lends itself very well to simultaneous production of electricity and heat.

Survey of Test Installations

There are today various test installations in the stage of construction or already in operation, and there are plans worked out in detail for new PFBC installations.

All this is especially the case in the United States, Great Britain and the German Federal Republic. In the Netherlands, a proposal was presented in late 1979 to the Ministry of Economic Affairs concerning the construction of a national PFBC development project, with the request that the funds for it be made available to the participating industries (Neratoom as representative of Kon. Mij. de Schelde, VMF/Stork and Comprimo) and the research institutes of TH-Delft, TNO and ECN. It is hoped that if the possibility is created, also the Netherlands will be able to take up the PFBC technology in a responsible manner and that the industries will be enabled, in the future, to design, build and supply installations.

Abroad, there are today three big projects, viz.:

the Curtiss-Wright project at Wood-Ridge (N.J., U.S.A.)
the IEA project at Grimethorpe (Great Britain)
the Bergbau-Forschung project at Bottrop (Federal Republic of Germany).

Table I gives data for the various projects.

The project most advanced is, undoubtedly, the Curtiss-Wright project, which is sponsored by the U.S. Department of Energy (7, 8). As Curtiss-Wright is now part of the Dorr-Oliver concern, the extensive experience of Door-Oliver on fluidized bed could be made available. Already much experience was gained with a PFBC test installation (figure 5) to examine the conduct of turbine blade materials in a small (75 kW) gas turbine. Here, virtually no erosion and corrosion was established when burning East-American coal with a high sulphur content (> 3% S) in a test of more than 1,000 hours. A 13 MW installation is now being built, and after that it is hoped to arrive at a 160 MWe demonstration installation as module which, through the combination of three similar modules, has been presented as a concept plan for a 500 MW installation.

The German project (at the Haniel Mine, Bottrop) is, at present, experiencing some delay in connection with a change of the gas purification system as well as of the choice of a suitable gas turbine. The reactor for this project, like the one for the IEA project at Grimethorpe, is delivered by the Vereinigte Kessel-Werke (VKW) at Dusseldorf, which belongs to the German Babcock concern.

The United States, the German Federal Republic and the United Kingdom are working together on the Grimethorpe project. The project is linked with the preparatory PFBC studies which the National Coal Board (NCB) has been carrying on for several years in its laboratory at Leatherhead (the former British Coal Utilization Research Association (BCURA), now the Coal Utilization Research Laboratories (CURL). Also for this project the choice of turbine has still to be made. The Dutch PFBC research activities were started in early 1979 at TH-Delft on the initiative of C. W. J. van Koppen, engineer. There they now have at their disposal a boiler, and they are at present preparing a second installation of 2 MWth.

The idea is to base the national research and development work in the Netherlands on the preparatory work of TH-Delft. It is hoped that this work will be incorporated in the National Research Program on Coal

Technology (NOK). A big installation of 50 to 60 MWth is proposed to be in operation in 1983/84. They are now looking for an industrial location with a good infrastructure. Figure 6 shows a simplified model of this test and demonstration installation, the main features of which have already been designed.

Prospects for PFBC Installations in the Netherlands

The specific advantages of the PFBC systems lie, in addition to the compact construction of the pressure boiler compared to an atmospheric fluid bed boiler, in the high yield of an integrated system and the possibility of being able to vary, within wide limits, the ratio between the electric capacity generated and the heat production given off, among other things, by using gas and reaction steam turbines. To this must, of course, be added the pro-environmental aspects of fluidized bed combustion in general.

In PFBC, a desulphurization degree of up to 95 percent is possible, preferably by means of dolomite as binder. Because of the higher pressure, also the NO_x emission appears to drop (6, 10).

The PFBC use seems to offer good prospects for industrial use, at a later stage also for use in the public electricity supply, perhaps in the capacity range of 100 to 300 MWe, and perhaps also for placement in ships in propulsion installations.

In the United States, PFBC is regarded as a very promising possibility of converting coal to electricity also in bigger plant units in an economic and pro-environmental manner. Studies (ECAS, Bechtel, EPRI) have shown that these systems are considerably less costly to build than systems based on coal gasification. For PFBC plus STEG units, an amount of $750 (1500 guilder) per KW is mentioned in these studies, comparable to a pulverized coal plant combined with flue gas desulphurization.

As for possible PFBC uses, the following uses may thus be conceivable:

1. Public electricity supply, whether or not combined with heat supply for town heating purposes.
2. Heat-power installations in industry.
3. PFBC installations aboard ships, for example in bulk carriers for coal transport.

The Market for PFBC

In connection with the following estimate of penetration possibilities for the PFBC technology in the Dutch energy economy, it should be pointed out that industrial gas turbines during the last 10 years have been developed to a degree of reliability comparable to that of reaction steam turbine installations.

In the Netherlands, 11 enterprises are now using a gas turbine in combination with a steam turbine, while 5 enterprises use a gas turbine without coupling to a steam cycle. With these installations, a total annual steam production of 12.5 x 10^6 tons was reached in 1978 according to data from the Society of Owners of Power Tools. This corresponds to a gas turbine share in the steam production of 19 percent.

Although natural gas, in principle, will still remain available as fuel for heat power installations with gas turbines and a high yield, there will, no doubt, be a demand for coal-fired gas turbine installations if these become available in the late eighties at an acceptable cost and with an acceptable reliability rate.

It applies already today that gas is 1.6 times more expensive than coal (based on a gas cost of 21 cents/Nm^3 and a coal price of 110 guilder per ton). This ratio could increase to approximately 2, which would already be the case with a gas price of 20 cents/Nm^3 and a coal price of 110 guilder per ton.

In the following, the penetration possibility of the PFBC technology for the various areas of use will be dealt with.

Electricity Production for Public Network

Although there is still a long way to go in the development of the PFBC technology, the generation of electricity in a plant based on the PFBC technique is an area of use which is promising.

A broad study (Stork), for example, thus showed that the pressure boiler for a central module of 150 MWe can be built in a cylindrical container with a diameter of 10 meter and a height of 25 meter. It is to be expected that by means of this compact design of the combustion area, a coal-fired plant may be built with a minimum need for base surface and a minimum of 'horizon pollution.'

According to the Energy Policy Report Part I (1979), the electric capacity of oil/coal-fired plants to be constructed by the year 2000 will be 13,800 MW (maximum) or 10,200 MW (minimum). On the average, thus 12,000 MW. On the basis of an expected coal consumption in plants of 13 x 10^6 tons/year in the year 2000 and an at present already existing capacity on the basis of coal (PNEM plant at Geertruidenberg, PGEM plant at Nijmegen) of 1,200 MWe, a capacity of 4,800 MWe on the basis of coal and also operated with coal will be added by the year 2000. The other plants will then either be built in such a way that they can switch from coal to oil, or they will be nuclear plants.

Part of this expansion could take place in the form of, for example, four PFBC installations with a capacity of approximately 200 MWe each. At an estimated investment of 1,500 guilder per KW, this electric capacity

(800 MWe) would require a total investment of approximately 1.2 billion guilder. The investment in the PFBC boilers will be part of it, at an estimated share of 15 percent corresponding to 180 million guilder.

Industrial Use

As already stated, the PFBC gas turbine system is viewed as an important possibility of use for the industries and certainly as the basis for industrial heat-power installations.

The installed capacity in heat-power plants is today approximately 1100 MWe, but it will, undoubtedly, increase significantly, perhaps to 3,000 MWe, and an installed capacity on the basis of coal of 2,000 MWe (at 10,000 MWth) thus appears to be a realistic possibility for the end of the century.

Of the capacity generated by the industries themselves today of 5.3×10^9 kWh/year, approximately 45 percent is generated in reaction plants, 28 percent in condensing plants, 25 percent with gas turbines and 2 percent by way of other methods. As the gas turbine is becoming increasingly attractive (the possibility of large savings, continuous technological development), and as, at the same time, part of the heat-power generation takes place in STEG plants, it is estimated that around the year 2000 approximately 50 percent of the total installed industrial capacity will be equipped with a gas turbine.

This implies an installed capacity of 1,500 MWe, in which context gas turbines play a role. It should be pointed out that the gas turbine can be enabled to take over part of the traditional reaction-steam market by applicatio of the PFBC technique.

These systems permit a lower power-heat ratio since the emphasis shifts in the direction of steam production as a result of the fact that the combustion space is carried out as water/steam cooled. Because of the possibility of choice whether or not to expand the steam by means of a reaction steam turbine to the desired process steam pressure, a very wide range arises in attainable power/heat ratios, whereby the installation has a broad area of use.

A cautious evaluation of the penetration of PFBC, on the basis of the future availability of reliable units, could approach 1/4 of the total capacity equipped with gas turbines, i.e. approximately 400 MWe. One can here think of, for example, 20 installations each of 20 MWe and 100 MWth. This will be coupled with an annual coal consumption of approximately 2×10^6 tons.

Town Heating

As concluded, among other things, in the BAGS report (11), and as is also regarded as a target figure by the NEOM, approximately 350,000 dwellings in the Netherlands could be connected with town heating plants around the year 2000. If the average connection capacity per dwelling is assumed to be 13.0 KW, the basic load can be assumed to be 40 percent of this capacity, thus 5.2 KW per dwelling. For this purpose, coal-fired heat-power plants can be built. Based on the--in the framework of fuel diversification--so desired essential penetration of coal as fuel for the production of the basic load heat (in heat-power generation!), for example put at 50 percent, 175,000 dwellings would thus, in this way, be provided with their basic heat load, corresponding to approximately 900 MWth. Having in mind heat-power plants with reaction steam turbines, this could then be coupled with an electricity production of approximately 600 MWe.

It can be assumed that part of this capacity of 900 MWth will be generated by means of PFBC installations. Their share will be limited in extent in connection with the rather low annual time of operation of the installations, which, for the production of this basic load heat, can be estimated at 3,500 h/year.

An estimated penetration of 25 percent seems justified, corresponding to 225 MWth. This would correspond to an electricity capacity of approximately 150 MWe. A small number of smaller units, for example three of each 50 MWe and 75 MWth is conceivable.

Ship Propulsion

As far as ship propulsion is concerned, it should be pointed out that, in this area, an important market could arise for Dutch industry if, indeed, a sufficiently reliable ship propulsion installation on the basis of the PFBC principle could be developed. For a big freighter, such as a bulk carrier of 100,000 tons, a capacity of approximately 20 MW is necessary. The compact design of a PFBC gas turbine installation could be of importance in this context. It is, however, very uncertain to what extent the PFBC principle will be used for this purpose, and, for that reason, no attempt will, therefore, be made to give an estimate of the degree of the penetration.

In summary, the possible use of the PFBC technology in the Netherlands by the year 2000 can be assumed as indicated in Table II.

Conclusion

The PFBC technology seems to offer very interesting prospects for the future use in the industrial and public energy supply sectors.

The advantages are primarily due to the fact that this technique makes it possible also with coal as fuel to use the good energy conversion properties of the gas turbine combined with a steam cycle; besides, a large variation in coal quality can be permitted, and the SO_2 and NO_x emissions can be reduced significantly. In the first instance, it seems that PFBC installations will be considered for industrial heat-power installations, subsequently also for the public energy supply.

The number of problems to be solved is, however, still very great, especially with regard to the construction and materials of the boiler and the pipes mounted in it, the gas purifying installation and the gas turbine (5,9) as well as the regulation of the entire process. There is occasion also in the Netherlands to launch an extensive research and development program in this area. In this way, the Dutch boiler and equipment industry can be linked with the development work already in progress in some countries, while the research institutes involved will be able to arrive at positive and applicable results in this area.

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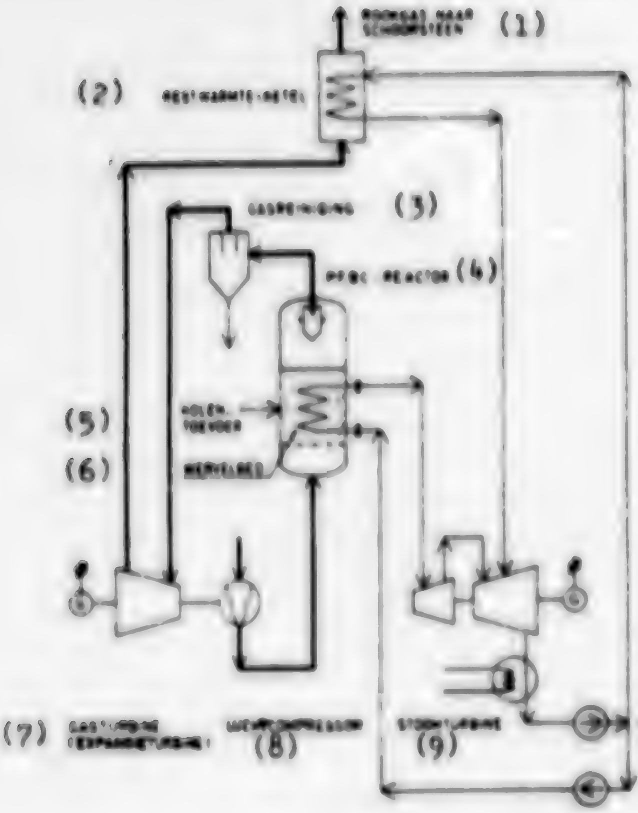

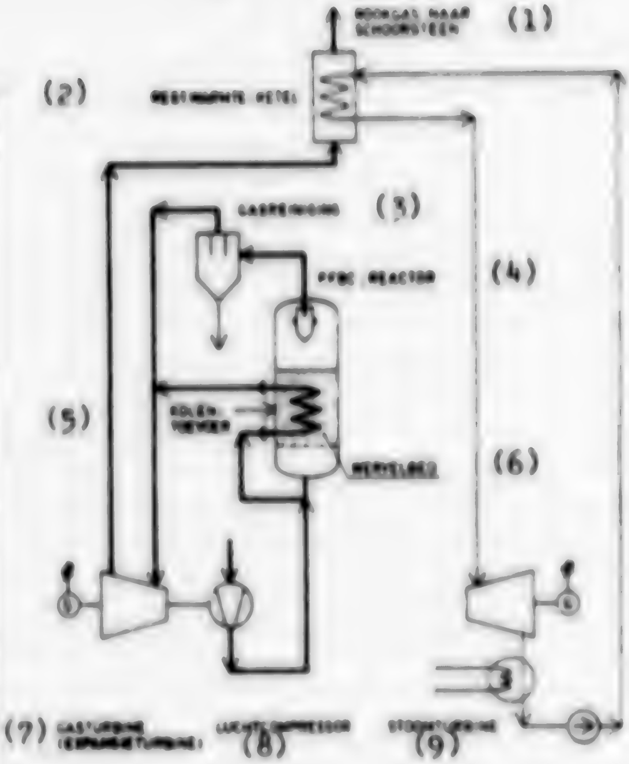

Figure 1. PFBC-STEG installation with water-cooled fluidized bed combustion area

Key:

1. Flue gas toward stack
2. Residual heat boiler
3. Gas purification
4. PFBC reactor
5. Coal supply
6. Fluidized bed
7. Gas turbine (expansion turbine)
8. Air compressor
9. Steam turbine

Figure 2. PFBC-STEG installation with air-cooled fluidized bed combustion area

Key:

1. Flue gas to stack
2. Residual heat boiler
3. Gas purification
4. PFBC reactor
5. Coal supply
6. Fluidized bed
7. Gas turbine (expansion turbine)
8. Air compressor
9. Steam turbine

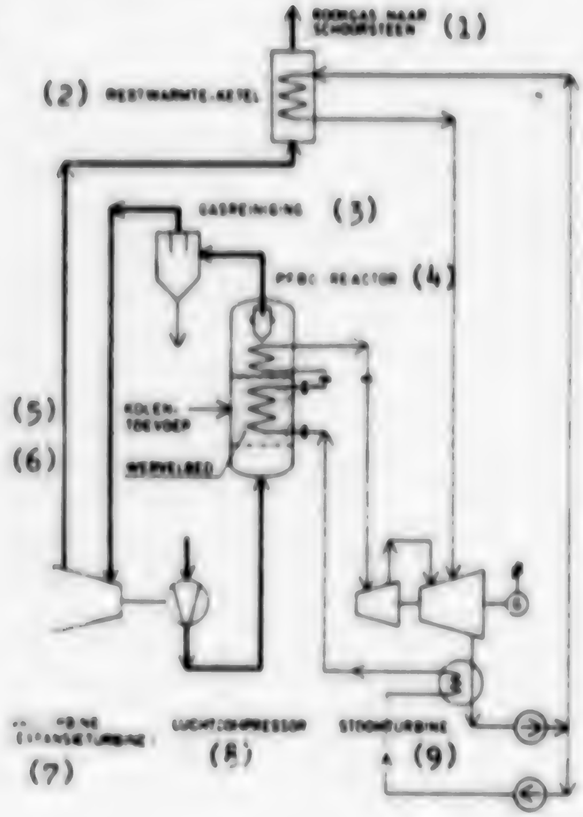

Figure 3. PFBC installation with electricity production exclusively through steam cycle

Key:

1. Flue gas to stack
2. Residual heat boiler
3. Gas purification
4. PFBC reactor
5. Coal supply
6. Fluidized bed
7. Gas turbine (expansion turbine)
8. Air compressor
9. Steam turbine

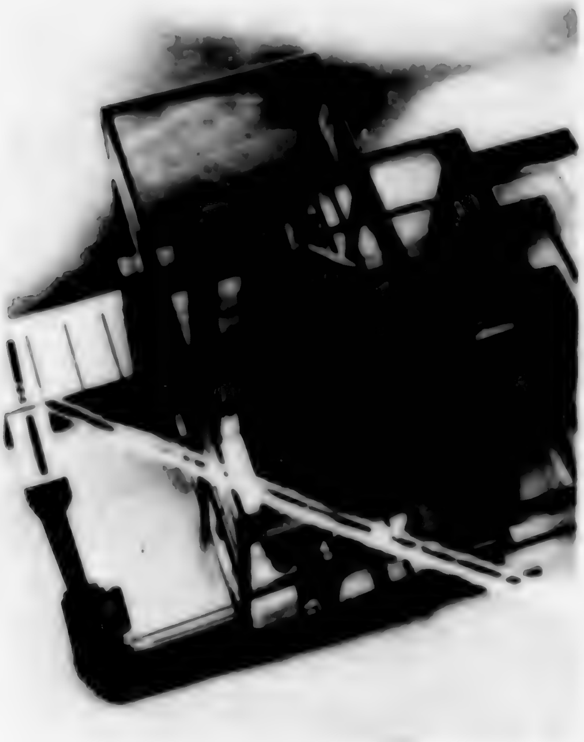

Figure 6. Model of 57 MWth PFBC installation as proposed by Neratoom working group

Table 1. SURVEY OF PFBC PROJECTS

Location (1)	(2) Enterprise Principal	(3) Start of operation (year)	(4) Capacity	(5) Diameter Fluid Bed (mm)
United States				
1. Wood-Ridge (N.J.)	Curtiss-Wright and DOE (small gasturbine plant)	1977**	1 MWth	900 Ø
2. Wood-Ridge (N.J.)	C-W PFBC Pilot Plant	1981 (6) (under construction)	13.5 MWe	3000 Ø
3. Linden (N.J.)	EXXON-Miniplant	1974**	1.4 MWth	250 Ø
4. Brilliant (Ohio) 'Tidd' power station	American Electric Power Co. and Stal-Laval and Babcock & Wilcox Ltd.	(7) 1983 (?) (still project study)	170 MWe (STEG)	
Great Britain (8)				
5. Leatherhead	BCURA/NCB Pilot Plant	1969**	4 MWth	1230 x 610
6. Grimethorpe	IEA Experimental Facility	(6) 1981 (under construction)	87 MWth	2000 x 2000
W. Germany (9)				
7. Bottrop	AGW/BMFT (Bergbau-Forschung)	1981 (?) (6) (under construction)	25 MWth (4 MWe)	3600 Ø
Netherlands (10)				
Delft	THD-1	Aug 1979**		250 Ø
	THD-2	Jan 1981	2 MWth	(600?) Ø
Petten	ECN	1981	5 MWth	600–1000 Ø
	ECN/EZ/Neratoom	(11)1983 (project study)	57 MWth	4000 Ø

** Installations which are in operation (or for which test operation is ready).

TABLE II. POSSIBLE PFBC USE IN THE NETHERLANDS AROUND THE YEAR 2000

	Capacity (MW_e)	Investment (fl. x 10^6)	Coal consumption (10^6 tons/year)	Assumed rate of penetration
Public electricity production	800	1200	2.0	16%
Industrial installations	400	800	2.0	25%
Town heating	150	300	0.2	25%
Ship propulsion	p.m.	p.m.	p.m.	-
Total	1350	2300	4.2	-

7262
CSO: 3102

BRIEFS

WORLD'S LARGEST PHOTOVOLTAIC PLANT--Two important reports--one relating to Puglia and the other to development of astrophysics in Italy--concluded the 68th National Congress of the Italian Physics Society in Bari. Puglia is interested in construction of the world's largest photovoltaic power plant. Of experimental type, it will be built within 4 years at most, in a predominantly level zone--perhaps in Tavoliere or Salento. It will cost 20 billion lire and will have maximum power of 1 megawatt in greatest sunshine, which is enough to power a train or provide electricity to 300 private residences. Professor Silvestrini of the University of Naples spoke about it, presenting the feasibility study done for the plant by ENEL [National Electric Power Agency], the CNEN [National Nuclear Energy Commission] and the Academy of Naples. How will it be installed? Photovoltaic panels distributed over a surface area of 1 hectare, suspended horizontally at a height of 6 meters, will convert sunlight directly into eletrical energy. It is not by chance that the power plant will serve an agricultural zone, since it has been observed that the sunlight curve coincides quite closely with that of electric-power consumption. [Excerpt] [Bari LA GAZZETTA DEL MEZZOGIORNO in Italian 22 Oct 80 p 12] 11267

CSO: 3102

MINISTER ANSWERS QUESTIONS ON WIND-ENERGY RESEARCH

Amstelveen ENERGIE SPECTRUM in Dutch Sep 80 pp 202-203

[Text] On 20 June 1980, Second Chamber Members Mrs. Lambers-Hacquebard (D'66 [Democrats of 1966]), Mr Lansink (CDA [Christian Democratic Appeal]), Mrs Epema-Brugman (PvdA [Labor Party]) and Mr Jansen (PPR [Political Party of the Radicals]) posed the following written questions for the minister of economic affairs:

1. May we assume that in the meantime the minister has taken congnizance of the Center for Energy Conservation's proposal for a National Program for Small Wind Turbines of 7 May 1980, presented to him for further development?

2. Does the minister intend to establish an energetic approach to the problem? Will the Center [for Energy Conservation] be involved in that? What activities has the minister already undertaken on this point? Has there already been a discussion with those who offered this proposal?

3. Why is less than 3 percent of the 18.5 million guilders in research money devoted to small windmills and has research actually taken place as to the potential of large windmills rather than small one? What evaluation of the generating potential and profitability of small windmills (up to 100 kw) as compared to large ones (more than 100 kw) does the minister hold, and on what is this evaluation based?

4. Is it known to the minister that the ECN [Netherlands Energy Research Center] estimates notwithstanding, according to other studies, producing electricity with small windmills is already economical in many cases?

5. Is it true that thus far hardly any space has been devoted to cost optimalization and studies with regard to the economy of wind electricity? If so, how does the minister plan to make good this deficiency?

6. Does the minister share the opinion that (in view of the location, prior history and specific expertise) it is not obvious that the ECN at Petten ought to remain the only coordination point for research into windmills (in particular as regards small windmills) and that some diversification with regard to approach and expertise can be desirable? If so, how does the minister plan to bring

about this diversification? Does he consider the conceptual research program mentioned in Question 1 to be an appropriate approach to this? What role does he see for the Center for Energy Conservation in the area of wind research, in addition to the wind research in Petten?

Additional information pertaining to Question 4:

In an article in ENERGIESPECTRUM for June/July 1978, Dr R. Van Der Wart (ECN) stated: "With the smaller systems of from 1-100 kw currently seen in practice, electricity is produced which is 10 to 20 times as expensive as that which is offered to us by the public power supply." However, a study by the Center for Energy Conservation indicates that generating electricity with small windmills is already actually economical in many cases.

Additional information pertaining to Question 6:

Working out another angle of approach could be worth the effort not only from the point of view of energy conservation, but also with respect to the chances for innovation and employment possibilities for intermediate-sized firms.

The minister of Economic Affairs answered those questions as follows:

1 and 2. The proposal, "National Research Program: Small Wind Turbines" from the Center for Energy Conservation (CvE) had already been brought to my attention before this question from the honored delegates [Second Chamber members] reached me. Discussion is currently under way with those involved. I cannot say just now when that discussion will be completed.

3. The brief goal and make-up of the National Research Program for Wind Energy (NOW) are given in the Energy Report, Part 1, pp 133 and following. The NOW is directed toward the possible applications of wind energy and makes no distinction between large and small windmills.

A careful study of the NOW budget of up to 18.5 million guilders shows that about 3.7 million guilders will be devoted to small wind turbines. That amount is divided as follows: Studies of small-scale applications: 0.32 million guilders; tip-vane studies: 0.86 million guilders; development, construction, and operation of the 5.5 meter diameter Vertical Axle Turbine: 2.5 million guilders.

Thus about 20 percent of the budget is being devoted to small windmills.

Besides that, research of a more general interest is taking place (meteorology, dynamic behavior of wind installations, electrical systems, etc.) which is of interest for large windmills as well as for small ones.

The research which is primarily directed toward large units has produced results at the same time which are of interest for smaller wind turbines. I am thinking here in particular of the methods of calculing the load values and fatigue phenomena.

The NOW is precisely aimed at obtaining insight into the potential and the economy of wind energy systems. In this, the possibilities of small windmills will also be studied. At this moment, no adequately based evaluation of the generating potential and the financial economy can be given. Furthermore, the expectation is that an important contribution to the energy supply will be made in particular by larger units of more than 1 megawatt.

4 and 5. The purpose of NOW is to study how and to what extent wind energy can make a contribution to the nation's energy supply. The principles are now being laid in NOW which will serve as the basis for studies of the economy of wind energy. These studies will be carried out during the evaluation of NOW.

It is known to me that there are studies with positive results with respect to the applications of small windmills. The principles upon which these studies are based (durability, safety, economical criteria), however, ought to be checked as to their accuracy.

Even though the ECN has not accepted the opinion that the application of small wind turbines is already economical, the ECN, too, feels that further study in this area is desirable. ECN's interest in small windmills can also be seen from the decision reached recently to establish a test station for small windmills at their research facility in Petten.

6. No, precisely in view of the location, prior history and expertise the Bureau of Energy Research Projects (BEOP) at the ECN seems to me to be outstandingly well suited to play a coordinating role in wind energy research in the Netherlands. I consider it important to centralize the coordination of the research as much as possible at one installation. In the course of NOW, BEOP has developed a good relationship with research institutes, companies of various sizes, lower governmental agencies and so on, so that BEOP can also fulfill a coordinating role in the research into the possibilities of small windmills. In view of the above, the "diversification with regard to approach and expertise" sought by the questioners seems to me to be adequately guaranteed.

The proposal "National Program: Small Wind Turbines" certainly contains some useful elements. In discussion with CvE and BEOP it will be determined to what extent these elements can be carried out. In my opinion, the parts of the CvE proposal which are aimed directly at stimulating the use of wind energy do not belong in a research program, not before the evaluation of the research is complete. Only after the completion of the research program can it be determined whether and if so how the use of wind energy ought to be furthered.

It will be determined in discussion with the CvE what role the CvE can play in NOW. For the time being, I am of the opinion that this ought to primarily an operational role. Naturally, the activities of the CvE outside of NOW are determined entirely independently by the CvE.

6940
CSO: 3102

DIRECTIONS, EXPENDITURES FOR R&D 1979-83 OUTLINED

Rome RELAZIONE PROGRAMMATICA in Italian Vol 1 80 pp 79-82

[Article: "Scientific Research"]

[Text] The positive tendency toward increasing state-participation commitment in the field of scientific research--a tendency particularly marked in 1978--will continue also in the coming years. It confirms the public entrepreneurial system's desire for a revival, a revival that cannot help but be supported by extensive, dynamic and pertinent activity in the field of scientific research.

Consider the fact that last year's forecast for the 5-year period 1978-1982 projected expenditures of a little more than 1 trillion; but the new, updated forecast raises the projections, for the period 1979-1981, to 2.9 trillion: an increase not much less than 200 percent.

The IRI [Industrial Reconstruction Institute] alone indicates, for the current 5-year period, total expenditure of 2 trillion, but without breaking it down--in relation to the last 3 years of the period--into the two big categories of "current expenditures" and "capital expenditures," or among the various sectors.

For now, a total amount is assumed as a guideline and will have to be detailed by sector as the medium-term research programs are defined. In many sectors in which the IRI works, the evolution of the present economic and energy situation may necessitate studies and procedural planning that are not precisely foreseeable today.

The ENI [National Hydrocarbons Agency] specifies that it will earmark 78.7 billion to capital expenditures and 503 billion for current expenses, 93 percent and 89 percent of it, respectively, absorbed by research and development in the sector of energy sources and chemisty; the balance of the amounts will involve nonferrous metallurgy and the mechanical sector.

The EFIM [Manufacturing Industry Holding and Financial Company] forecasts a total of 270 billion, 59.7 percent of it for capital expenditures and 210.3 [as published] for current expenses. The greater part of the total sum (about 84 percent) will be earmarked for research and development in the many areas in which the EFIM operates and which involve a vast range of production, including several that are technologically very sophisticated; 10 percent and 6 percent, respectively, are for aluminum metallurgy and various other activities including, among other things, the glass sector.

For the 5-year period, the figures, even when specified, can only have a guideline character in the direction of greater commitment in research. From this point of view, their magnitude is very significant, also because they encompass and further in a timely manner, and translate into specific operational purposes, the policy which the government is carrying forward, with legislative provisions of undoubted interest, but which has not yet been activated in concrete terms. Among these, one should recall those in favor of research in the electronics industry, the special project for "applied scientific research" in the Mezzogiorno, and the finalized programs of the CNR [National Research Council], which, unfortunately, are running into difficulty in getting under way.

Within the framework of a very promising 5-year program orientation are the programs for the initial years of the period, the amounts specified for which express specific short-term actions.

In 1979 there is a new, sharp increase in expenditure over the preceding year: the total planned comes to 468.7 billion lire--an increase of 35.2 percent over 1978. The major increases are for energy sources and chemistry (43.6 percent), mechanical industry (42.2 percent), electronics and telecommunications (24.7 percent), steel and metallurgy (30.4 percent).*

The sharp increases are explained by the need for innovation, which is the indispensable condition for tackling the new situations that have come about in several sectors in which, in the coming years, there will be considerable modifications in production processes and in the products themselves. Consider the problems, on the research level, that arise with regard to energy sources, the thermoelectric and nuclear industry, automotive vehicles and their use, aerospace, electronics. Alternative energy sources, with regard to which several programs are already defined and others will be worked out, open up a vast field of research, as do also the innovations in the field of the utilization of coal. No less important is the research that will have to be undertaken in order to test new types of fuel for traction.

In particular, we stress the commitment to applied research in the electronics sector, which at the moment absorbs about half of the sums allocated by the IRI for research proper--a commitment connected with the big systems projects, in addition to technological projects, in the field of telecommunications. The Proteo project in electronic switching and the Sintra project in digital-type transmission should be mentioned.

In the aeronautics sector, the program provides for important research and experimentation particularly within the framework of development of the Boeing project; in the helicopter field, production will be developed that does not depend or foreign patents and know-how and that will be aimed at acquiring new basic technologies for fabrication of structures in composite materials to be used for helicopter blades.

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* The increase in this last-named sector, though, is influenced partly by inclusion of the data relating to the research done by the enterprises of the former EGAM [Agency for the Management of Mineral and Metallurgical Concerns] that have gone over to the ENI--data that it was not possible to determine for 1978, and the total amount of which for 1979 is around 2.6 billion lire. For the former EGAM enterprises that have gone to the IRI, specification of the expenditures for scientific research and development will be done starting with the following year.

The EFIM is also carrying on interesting research toward definition of new technologies and installations relating to agricultural irrigation, of importance specifically to the Mezzogiorno, as well as studies in the recycling of solid wastes and treatment of the sludges resulting from waste water.

Finally, it is planned to build in Sardinia an aluminum-research center which, among other things, will work on perfecting special alloys and solar panels.

The total body of research that has been cited, and that constitutes only the most significant aspect of the vast and articulated activity of the state participation in the specific field of scientific research, will characterize the commitment by the state-participation enterprises in this field for a number of years.

In 1980, activity along the lines briefly described and along the new ones that should emerge from the evolution of the economic and market situation--lines which the state interests are in a position to take up promptly, translating them into adequate activities on the research level--will continue and be developed.

In 1980, on the basis of the forecasts, the expenditures for research and development will come to a grand total of 542.9 billion, for an increase of 15.8 percent over the preceding year. The total will break down into 69.4 billion for capital expenditures and 473.5 billion for current expenses.

The biggest total expenditure will be for the mechanical industry--221.7 billion, about 41 percent of the grand total. This high percentage is explained by the large number of fields that make up the sector and by the fact that research is of primary importance in some of them. In this regard, we need only mention the expansion of the already vast range of activity of those fields relating to installations and technologies in the energy sector. The research prospects that open up in the area of automotive vehicles because of the feared scarcity of petroleum products are of undoubted importance. There is also the fact that the working processes in the mechanical industry, which has to cope with strong international competition, are subject to continual technological refinements.

The electronics and telecommunications sector,--we mentioned above the technology commitments and deadlines in this sector--will absorb 163.4 billion, more than 30 percent of the total, while the share of the hydrocarbons and chemicals sectors will drop to about 19 percent, at 101.4 billion. For these sectors, after 1979's strong commitment, it will be a year of settling in and analyzing the evolution in the energy and chemical fields.

In steel and metallurgy, 33.5 billion will be spent on research, for about 6.2 percent of the total; in the shipbuilding industry, 10.1 billion (not even 2 percent of the total); in radio and television, 7.1 billion (1.3 percent); in miscellaneous activities, 5.2 billion (0.9 percent); and on highways, 0.4 billion (0.1 percent).

Going on to the subject of the available resources of experts and researchers engaged in research, it will be recalled that at the end of 1977, a drop in the number of personnel (full-time-equivalent personnel) as compared with the preceding year was complained of. By the end of 1978, the shortfall--about 1,000--had been largely made up; at that time, the number of personnel had risen to 12,242 from the 10,276 of December 1977. As regards 1979, a further significant increase in the number of personnel is expected; it will rise to 13,769.

1) (in milioni di lire)

	1978			1979			1980			5) Variazioni % della spesa totale	
	2) Spese in conto capitale	3) Spese correnti	4) Totale	2) Spese in conto capitale	3) Spese correnti	4) Totale	2) Spese in conto capitale	3) Spese correnti	4) Totale	6) 1979 su 1978	7) 1980 su 1979
8) Siderurgia, metallurgia e attività connesse	1 928	21 851	23 779	4 294	26 703	30 997	4 853	28 685	33 538	+ 30.4	+ 8.2
9) Meccanica (b)	2 848	126 045	128 893	10 596	172 629	183 225	18 510	203 163	221 673	+ 42.2	+ 21.0
10) Cantieri Navali	826	6 763	7 589	1 170	7 725	8 895	1 450	8 667	10 117	+ 17.2	+ 13.7
11) Elettronica e Telecomunicazioni	13 846	102 981	116 827	22 707	122 968	145 675	21 472	141 961	163 433	+ 24.7	+ 12.2
12) Idrocarburi, chimica e attività connesse (c)	10 462	51 908	62 370	19 815	69 770	89 585	20 794	80 617	101 411	+ 43.6	+ 13.2
13) Radiotelevisione	600	4 865	5 465	600	5 590	6 190	600	6 540	7 140	+ 13.3	+ 15.3
14) Autostrade	—	295	295	—	337	337	—	362	362	+ 14.2	+ 7.4
15) Varie	318	1 173	1 491	1 125	2 666	3 791	1 680	3 504	5 184	+ 154.3	+ 36.7
4) Totale ...	30 828	315 881	346 709	60 307	408 388	468 695	69 359	473 499	542 858	+ 35.2	+ 15.8

16) (a) Dati consuntivi per il 1978 e di previsione per il 1979 e 1980. I dati comprendono le spese per ricerca esterna.

17) (b) È compresa per intero la spesa dell'Istituto di Ricerche Breda che svolge attività di ricerca anche in altri settori; è compresa inoltre la spesa per ricerche nel settore elettronico effettuate dalle imprese meccaniche dell'E.N.I.

18) (c) Comprende anche il settore nucleare dell'E.N.I. e le attività di ingegneria e servizi connesse al ciclo degli idrocarburi.

[Key for Table 18--The State-Participation Firms' Capital Expenditures and Current Expenditures for Scientific Research and Development in the Years 1978, 1979, 1980 (a)]

1. (in millions of lire)
2. Capital expenditures
3. Current expenditures
4. Total
5. Percentage variations of total expenditure
6. 1979 as compared with 1978
7. 1980 as compared with 1979
8. Steel, metallurgy and related activities
9. Mechanical industry (b)
10. Shipbuilding
11. Electronics and telecommunications
12. Hydrocarbons, chemistry and related activities (c)
13. Radio and television
14. Highways
15. Miscellaneous
16. Final data for 1978 and forecast data for 1979 and 1980. The data include the expenditures for external research.
17. This includes all of the expenditure by the Breda Research Institute, which carries on research in other sectors also; it also includes the research expenditure in the electronics sector by the mechanical-industry enterprises of the ENI.
18. Including also the nuclear sector of the ENI and the engineering activitiies and services connected with the hydrocarbons cycle.

11267
CSO: 3102

UDC 625.39:621.318

STATUS OF DEVELOPMENT OF ELECTROMAGNETIC HIGH-SPEED RAILWAY SYSTEMS

West Berlin ZEITSCHRIFT FUER EISENBAHNWESEN UND VERKEHRSTECHNIK in German Aug/Sep 80 pp 233-240

[Article by R. Zurek, graduate engineer, head of the Applications Division in the Transport Systems Section of the Krauss-Maffei Company, Munich]

[Text] 1. Introduction

After [years?] of development of electromagnetic suspension technique ... past.* The current status of development will be described here in terms of the Emsland TRANSRAPID test facility (TVE) project, a test facility which is being constructed in the northwestern portion of the FRG. The design and definition phase of this facility has been completed and it is now in the stage of development and actual construction.

The developmental focal points of recent years have been:

i. functional testing of new carriage, guidance and propulsion components in various operational modes and configurations on smaller "in-house" test facilities [1],

ii. the actual construction of design vehicles for passenger and goods transport with various propulsion principles [2],

iii. parametric road layouts and route studies [3] and

iv. the development of a model for the technical and economic description of rail-borne transport systems [2].

Important results of this interim period were:

i. the restriction of the support program of the Federal Ministry of Research and Technology (BMFT) to the further development of electromagnetic suspension [4],

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* The first sentence of the original text seems to have been misprinted--translator's note.

ii. the development of the design concept of the so-called "magnetic wheel,"

iii. modification into a synchronous longitudinal stator propulsion system,

iv. the construction and operation of the demonstration facility for magnetic suspension technique at the International Transport Exposition [IVA] in Hamburg, 1978/1979 [5] and

v. the definition of the area of application of EMS technology [6].

With the IVA demonstration facility the development program, after the phase of component development and of functional testing, entered into the phase which is close to actual application, namely a phase of which the focal point is the construction and operation of the TVE. Investigations relating to the spectrum of possible uses of a magnetic high-speed train yielded two areas of application:

i. high-speed connections between two centers of high-density traffic with distances of 50 to 100 km traveled at speeds about 300 km/hr and

ii. a high-speed train network in Europe with distances of about 150 to 200 km between stations. The velocity of the system is 400 km/hr.

These potential domains of application characterized the goals and design of the TVE.

2. Goals and Design of the TVE

The goals of the TVE may be listed as:

i. long-term testing of a practicable passenger vehicle at 300 km/hr;

ii. extension of the speed range up to 400 km/hr;

iii. derivation of technical, economic and operational data as a basis for evaluating the utility of the electromagnetic high-speed train;

iv. completion of the process of obtaining official approval of the system for public transport and

v. demonstration of the nature and magnitude of environmental problems resulting from the noise and the optical appearance of an elevated roadway.

With this catalog of goals in mind several locations were investigated in the FRG [7]. The most suitable location turned out to be that in Emsland north of Meppen. The terrain, existing buildings and use of this region permitted the construction of a closed track having routing parameters [8] which previous routing studies have shown to be favorable. The 31.5-km-long path contains two turning loops which are connected by means of high-speed switches to the intermediate straight route. The test center at Lathen may be reached via a slow-speed switch (Figure 1). A "standard trip profile" in which the line is traveled over twice (once in each direction) via the turning loops consists approximately half of curves and half of straight sections and is 77 km long. Thus it corresponds approximately to an intercity high-speed line with regard to its mean route length, travel time and number of curved sections.

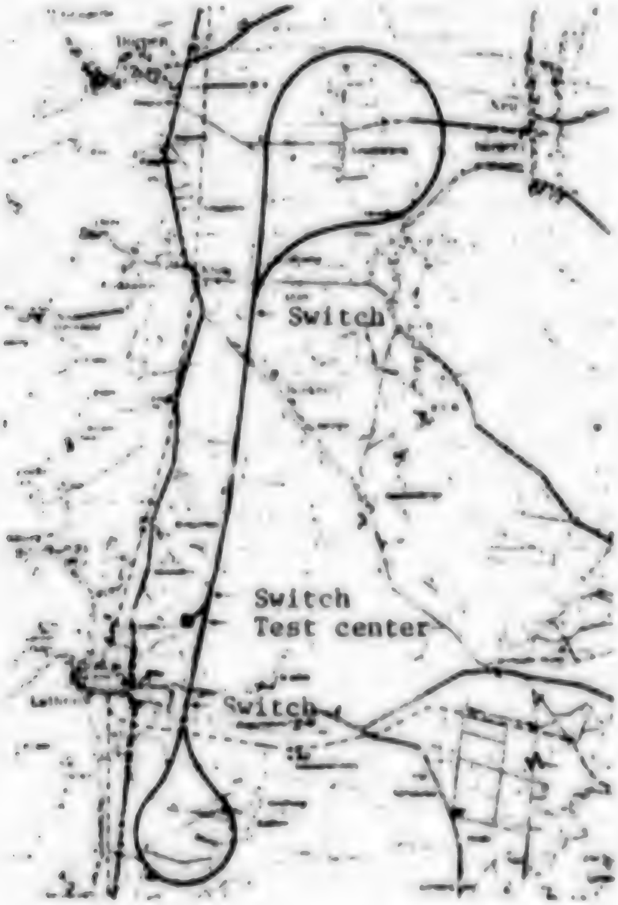

Figure 1. Test route in Emsland.

With a maximum bank of 12° at curves the turning loops may be traveled at 260 km/hr in the north end (R = 1,690 m) and 200 km/hr in the southern (R = 1,000 m) (see Figure 9) with a free lateral acceleration of 1 m/sec^2 not being exceeded. The maximum velocity of 400 km/hr can be attained over a straight length of about 1 km traveling approximately in the range of the usual testing ... direction* (Figure 1). In addition to radii from 500 m to 6,000 m the route also contains sinusoidal transition curves and S-curves, vertical arcs, the superposition of horizontal transition arcs upon vertical arcs and also short stretches of route having longitudinal grades of 35 percent. The exact list of routing parameters employed may be found in [7].

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* Gap in original text--translator's note.

In addition to a maintenance shed with associated repair shops the test center contains the operations control center and the power supply substation for the route. The technical design features of the track, of the propulsion system and of the vehicle are described in the following sections.

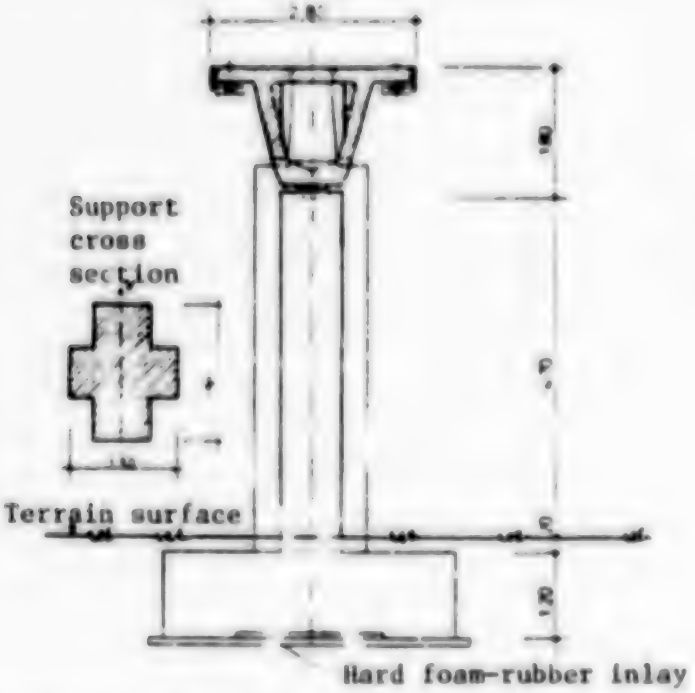

Figure 2. Cross section of track and support (drawing Dickerhoff and Widmann).

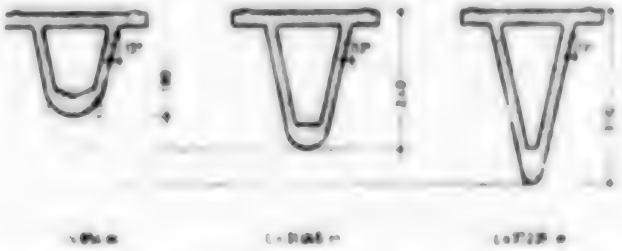

Figure 3. Route track cross sections for the three span dimensions (drawing Dickerhoff and Widmann).

3. Roadway

3.1. Suspension Structure

The roadway has been constructed over the entire route length as an elevated structure having a clearance underneath amounting to at least 5 m. The elevated design, which suggests itself in view of the pulling action of electromagnetic suspension, has already been shown in the earlier routing studies to be advantageous.

According to the proposal submission request for the first construction section, 9.4 km of route length, lying for the most part in a straight part of the route north of the test center, is designed as a prestressed concrete suspension structure. Figures 2 and 3 show the cross sections of track and support with the standard span dimension of about 25 m and the cross sections of tracks having spans ranging from 31 to 37 m. Tracks for spans up to 31 m are prefabricated in a field factory. Supports and foundations are made of locally mixed concrete. The tracks operate as single-span [Einfeld] tracks and are laid polygonally in curves.

In order to obtain as cheaply as possible high degrees of accuracy in track laying and in locating functional surfaces of the roadway a consistent distinction was made between the laying accuracy of the suspension structure and that of the rail installation. Following this method the suspension structure was laid with total deviations from ideal position amounting to about ±20 mm. The bearing upon the supports can be corrected later by a further ±20 mm if foundation locations exceed allowable values.

3.2. Roadway Equipment

In the case of a standard track position deviations of about ±5 mm are obtained under all loading and temperature conditions on the one hand by means of a suitable suspension structure design and on the other by means of an extensively automated track-laying procedure together with correspondingly designed fastenings for the rail equipment. The most important functional surfaces, which during operation must support higher loads are the stators for carrying and propelling the vehicle, the guiding tracks for guidance and mechanical braking and the sliding surfaces for setting down the vehicle.

Figure 4 shows in cross section the fastening and also the manufacturing principle: stator package and guide rails are integrally fused in with bolts or fishplates in recesses which have been provided in the collar plates [Kragplatten]; the guide rail is wedged against these. After the rails have been laid the sliding surfaces are produced by milling off concrete topping strips on the upper side of the collar plate. Thus they consist of built-up concrete.

research and development of effective principles of the construction of these complexes, hierarchical structures combining them into systems and also technical means required for their realization.

One of the first results of the work in this field was the creation and introduction of such complexes on the 500 kv electric power transmission lines from Kuybyshev to Moscow and Volgograd to Moscow and later on other 330-500 kv electric power transmission lines. The work with respect to improving this complex performed on the basis of the electromechanical relays permitted significant improvement of its characteristics, and it is being used to the present time. In addition, the institute jointly with other organizations and industry has developed a new complex based on semiconductors and microelectronics, which has significantly improved characteristics.

The emergency automation as a complicated complex of hierarchical centralized systems and local devices functionally connected by means of remote information transmission channels was formed in the last 15 or 20 years, and the leading role belongs to the institute in its formation, the development of the principles and methods of calculation. The institute has developed a series of emergency control complexes using the most modern principles and technical means. According to the operating index the introduction to the operation and maintenance of the emergency control complexes has permitted an increase in carrying capacity of the intersystem couplings of the integrated power system of the USSR by 7 million kilowatts.

The work of the institute to create guidance instructions with respect to relay protection which are the basic document in the formation of the technical policy within the scales of the entire country must be noted. Along with the fulfillment of important planning operations, the problems of the institute for the 11th Five-Year Plan in the field of relay protection, emergency automation and stability are as follows: completion of the development of protection complexes and emergency automation based on using the achievements in the field of microelectronics and their introduction into design practice; studies and development of the principles of executing relay protection and emergency automation systems using microcomputers; the study of the possibility of computing protection which depends little on the operating conditions of the electric power transmission lines; the development and investigation of measures and means of increasing the carrying capacity and the stability of the electric power transmission line; the study and development of the hierarchical structure of the emergency automation system of the USSR integrated power system providing for minimimization of losses, the creation of an automated design system, and, above all, the set of problems of selecting the settings of the relay protection devices and emergency automation, batching of the control inputs and the regions of stability of the power systems.

The Energoset'proyekt Institute is the head organization for the design of the Energiya OASU [branch automated control system].

During the 9th and 10th Five-Year Plans scientific research and planning and design work was done aimed at the creation and development of:

The Energiya OASU;

Automated power system control systems (ASU ES);

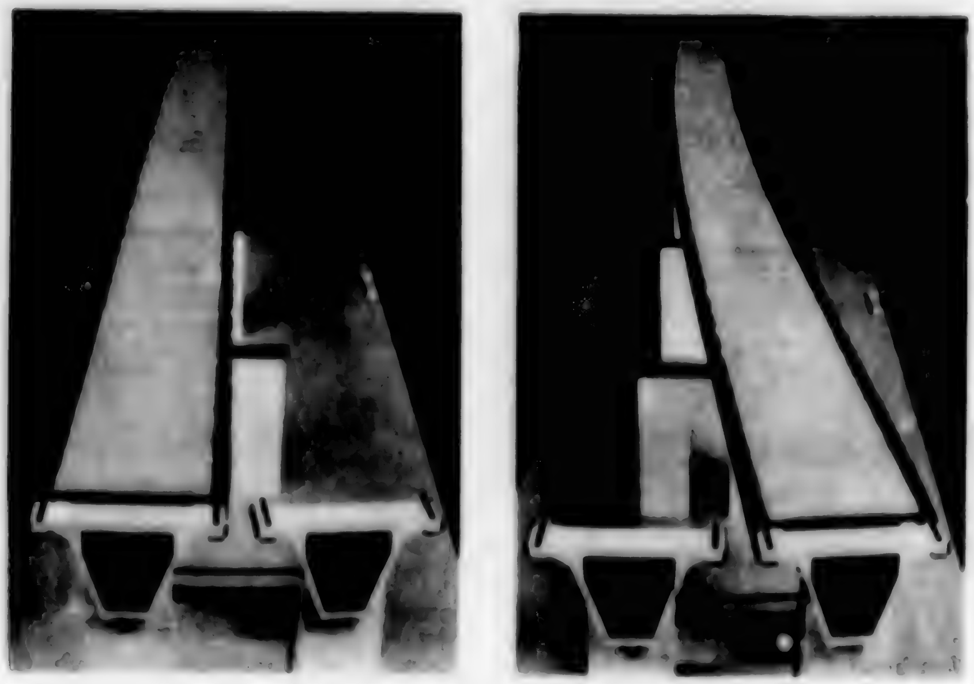

Figure 6. Switch (Krauss-Maffei plant photo).

The bending beam is supported at every 13 m (slow-speed switch to the test center) or every 19 m (high-speed switches connecting into the turning loops) and is held by bearing frames. These support points are also the points of application of the position-changing drives. Figure 7 shows in cross section the principle of position change by means of asynchronous motors, transmissions, positioning arms and guide bar brackets on the track. The lateral shift of the track is accomplished on running wheels whose axles at the same time take up the thermal expansion of the through track. Thus the bearing at the branching point of the track is designed as a fixed bearing. The switch safety design provides for a consistent separation--even in terms of structural components--of guidance functions (switching on and switching off of propulsion in normal operation and in a trouble situation) and safety functions (separate extreme-position indicator, actuation of locks). Table 1 shows the most important technical data of the switches.

Table 1. Data for the TVE Switches

Switch positioning time	about 20	sec
Maximum velocity for through travel over switches 1 and 2	400	km/hr
Maximum allowable branch-off velocity		
Switch 1	100	km/hr
Switch 2	200	km/hr
Maximum lateral acceleration in switches 1 and 2	1.5	m/sec^2
Length of switch 1	67,079	m

Table 1 (continued)

Length of switch 2	132,095	m
Switch radius in the circular arc between the transition arcs (klotoid-shaped at the switch beginning and switch end)		
Switch 1	499.5	m
Switch 2	2,061.0	m
Side jerk at switch 1	3.3	m/sec^3
Side jerk at switch 2	4.5	m/sec^3
Maximum thermal expansion gap at the switch end		
Of switch 1	60	mm
Of switch 2	120	mm
Power requirement of switches 1 and 2	about 40	kw
Support distances		
Switch 1	about 12.5 to 13.5	m
Switch 2	about 18.5	m

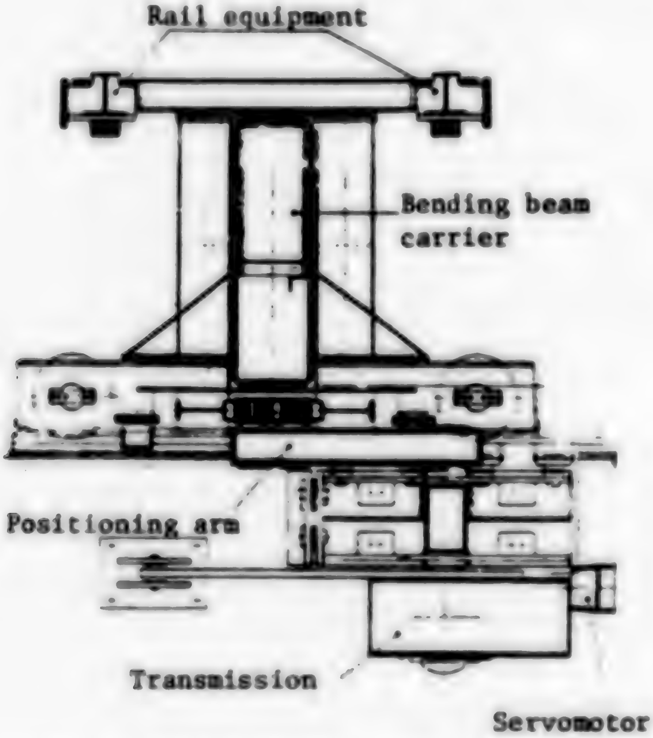

Figure 7. Principle of switch displacement (drawing Krauss-Maffei).

4. Propulsion System

4.1. Design

As stated in the beginning in recent years there has been a decision in favor of the so-called longitudinal stator propulsion system. A special form of this electrical synchronous propulsion is the combination of the functions of "support" for the vehicle and of vehicle "propulsion" [9]. This form has been selected both in the IVA demonstration facility and also for the TVE. The thrust is established by the interaction of a traveling wave generated in the windings of the stators with the magnetic fields which serve to carry the vehicle. To this end the vehicle-supporting magnets are designed as longitudinal flux magnets and the stator package is encased in sheet metal.

The velocity of the vehicle is established by a substation in stationary position through suitable variation of frequency, current strength and pole position between vehicle and traveling wave. By changing the pole position both thrust and braking forces can be generated so that the propulsion is also used as an electrical brake. The determination of the pole position is accomplished by the previously mentioned pole-position detection system INPO on the side of the roadway.

Figure 8 shows a chart of the entire propulsion system which draws its power totaling 10 MVA from the 110-kv public power system. The power is transformed down and fed via a DC intermediate circuit to two direct current-alternating current inverter blocks (WR blocks) each carrying 17 MVA. The WR blocks each feed a route cable running parallel to the route with variable voltage between 0 and 4.24 kv and frequencies from 0 to 215 Hz. In the case of low velocities or low frequencies the power is fed directly and in the case of greater velocities via transformers.

To reduce the power requirement and to improve efficiency the winding in the stators is subdivided into sectional circuits which can be alternately connected via route circuits to one of the two route cables. Because of the special thrust requirements for attaining 400 km/hr on the relatively short route of the TVE these sectional circuits are representative only to a limited extent.

In practical applications the section length will lie between 600 m in the accelerating stretches and 2,000 m in the high-speed stretches. Through control logic that sectional circuit will be switched on in which the vehicle happens to be located. Shortly before exiting into the next sectional circuit this latter will be likewise switched on in order to avoid interruptions of thrust, the power being alternately supplied from the two WR blocks (trestle bridging process). The route circuits are provided in the form of vacuum relays having 10^6 switching cycles with the circuits of two neighboring sections being placed in a station housing. The traveling wave winding consists of a specially developed 10-kv cable for about 1 ka of current load. The cable possesses a conducting outer mantle for grounding.

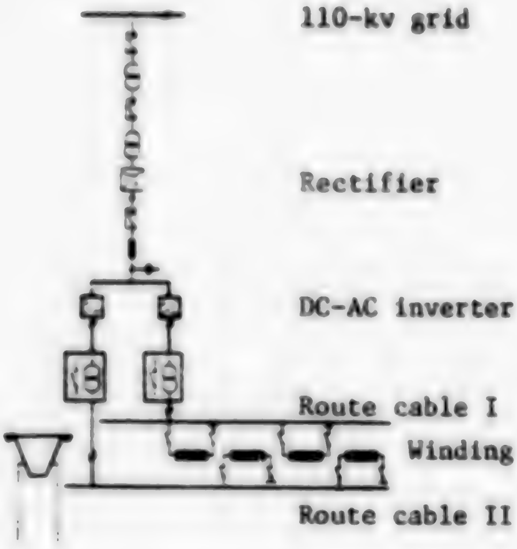

Figure 8. Chart of the total propulsion system.

4.2. Travel Performance

The propulsion is adapted to the goals of the TVE and dimensioned for two travel cycles:

i. the standard cycle of about 80-km length and a maximum velocity of 300 km/hr (Figure 9) for the cruising speed test and

ii. the maximum velocity cycle of 80-km length and 400 km/hr over a length of 1 km (Figure 10).

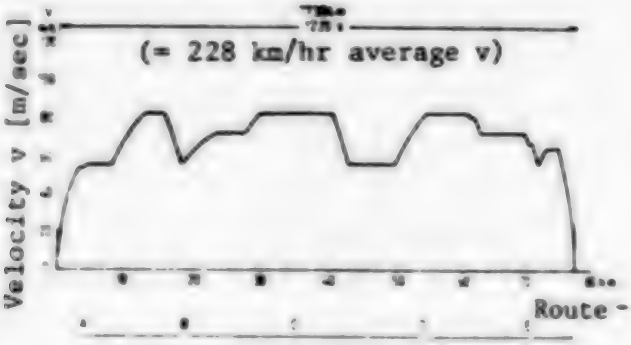

Figure 9. Standard cycle.

Parameters of the standard cycle are a mean velocity of 228 km/hr or a travel time of 20 min with accelerating and braking phases as well as velocity interruptions at the switches (200 km/hr in the branch-off) being included in the calculation. The energy requirement for the fully occupied

122-ton vehicle amounts to about 960 kwh, the maximum power amounts to 9.7 MW and the power averaged over the travel cycle amounts to 3.9 MW. In the high-velocity cycle 243 km/hr travel velocity or 19 min travel duration are attained. Here the energy consumption is around 1,200 kwh, the maximum power is 9.6 MW and the mean power around 5.3 MW. In this travel cycle the vehicle is only partially occupied and weighs 108 metric tons.

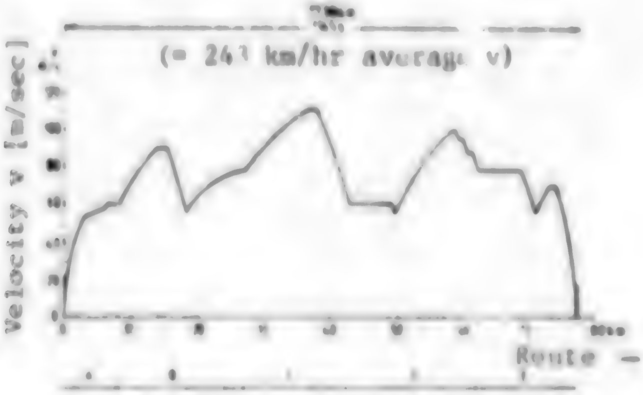

Figure 10. Maximum velocity cycle.

5. Vehicle

5.1. Principal Data

The vehicle consists of two identical sections with a total of 196 seats and 60 square meters of usable standing area (Figure 11). It is 54.2 m long, 3.7 m wide and 4.2 m high. The internal height of the car body is 2.1 m, the height above the upper edge of the roadway is 3.7 m. The weight empty is 102.4 tons, the standard cycle useful load is 20 tons and 6 tons in the maximum velocity cycle. For reasons to be explained later the vehicle can be driven only when both sections are coupled.

Figure 11. The vehicle (Krauss-Maffei plant photo).

Figure 12 shows the resistance as a function of velocity with the resistances plotted being those from aerodynamics, braking power of the guiding magnets and braking power of the linear generator for contactless on-board power supply. Figure 13 shows the corresponding mechanical power consumption for 400 km/hr and 300 km/hr and the distribution of the total required electrical on-board power of 0.4 MW. The circular areas are in each case a measure of the magnitude of the power.

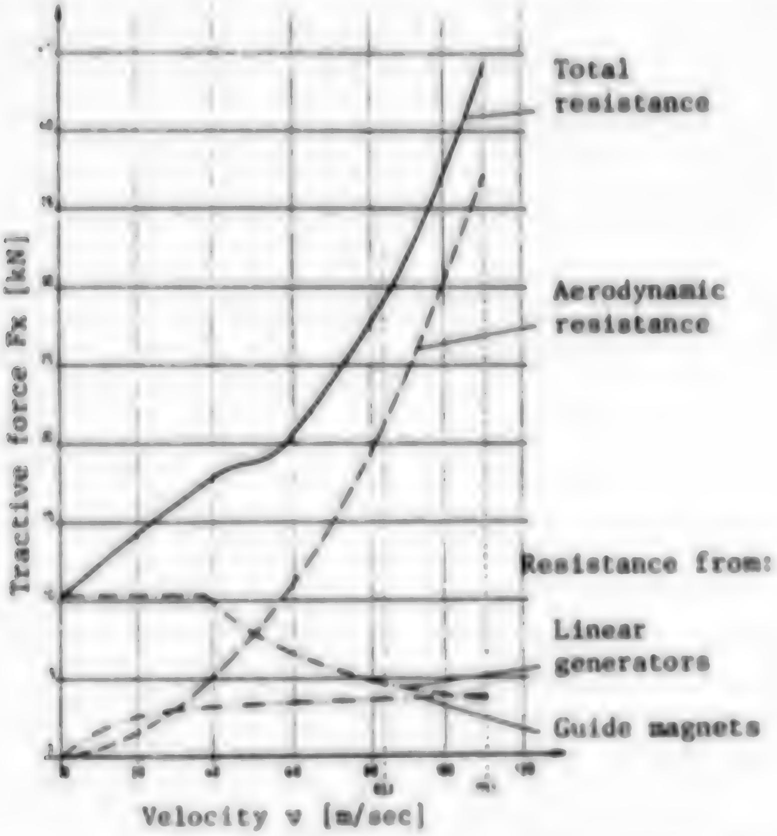

Figure 12. Travel resistance of the TVE vehicle TR 06.

By means of favorable aerodynamic shaping secured by means of model tests [10] in a wind tunnel (Figure 14) it was possible to keep the mechanical power of the vehicle below 5 MW at 400 km/hr. Moreover, it may be seen that the increase in velocity from 300 km/hr to 400 km/hr requires a doubling of mechanical power. The power fraction (electrical) of the electromagnetic carrying and guiding system as a fraction of the total power (mechanical) amounts depending upon the velocity to something between 5 percent and 10 percent.

5.2. Carrying/Guiding System and On-Board Power

The car body of each section of the vehicle rests via a secondary shock absorption system with rolling stabilizers upon four suspension undercarriages which in turn carry 32 supporting magnets and 28 guiding magnets with associated measuring and power electronics. The vehicle is thus almost over its entire length supported and guided by a continuous series of magnets. The articulation of these magnets to the suspension undercarriages is accomplished via a magnetic wheel design [11] in order to enhance the availability of the suspension system. The magnetic wheel possesses magnets individually steered parallel to guides and supported via mechanical springs.

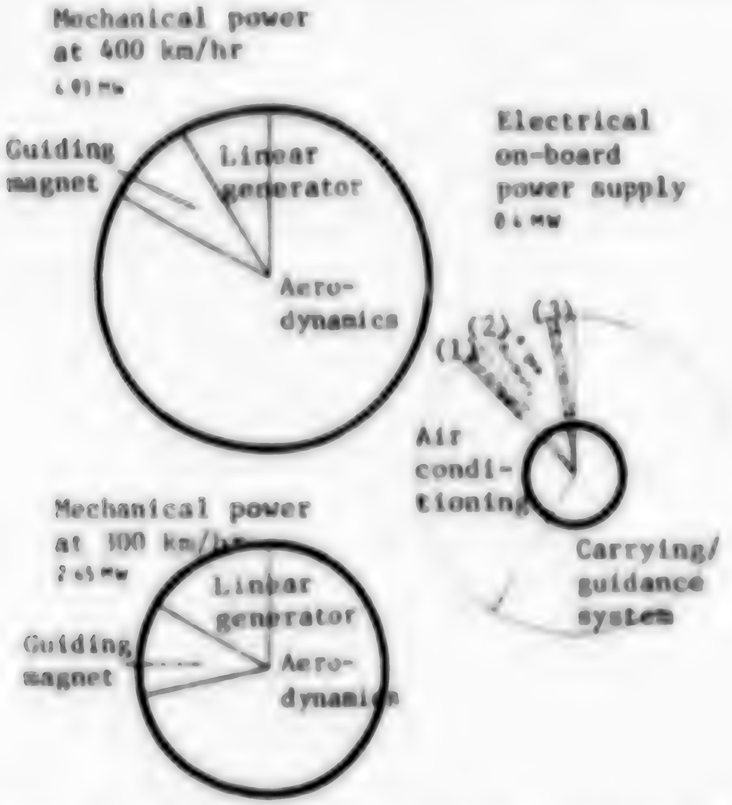

Figure 13. Power budget for the TVE vehicle TR 06.

Key: 1. On-board control generator
2. General on-board power supply
3. Test [?, illegible]

This mechanical individual suspension is supplemented by the installation of a decentralized unit composed of measurement pickups, control devices and power regulators associated with each magnet and checking the correctness of the suspension state. By means of this design the suspension capability of the vehicle is still assured even when two arbitrary magnets in each section have failed to function.

Associated with the decentralized design of the magnetic wheel there is also the redundant structure of the on-board energy supply component of the carrying and guidance system (Figure 15). A buffer battery is arranged for each section and each one of these supplies a separate busbar with 440 v DC.

The two busbars are drawn through both sections. At each busbar half of the magnets of a section are suspended via fuses. Upon failure of one busbar the carrying power of the remaining magnets suffices to initiate a controlled letdown of the vehicle upon slide runners.

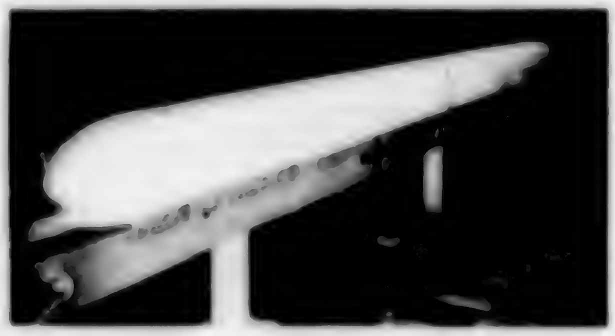

Figure 14. Favorable aerodynamic shaping.

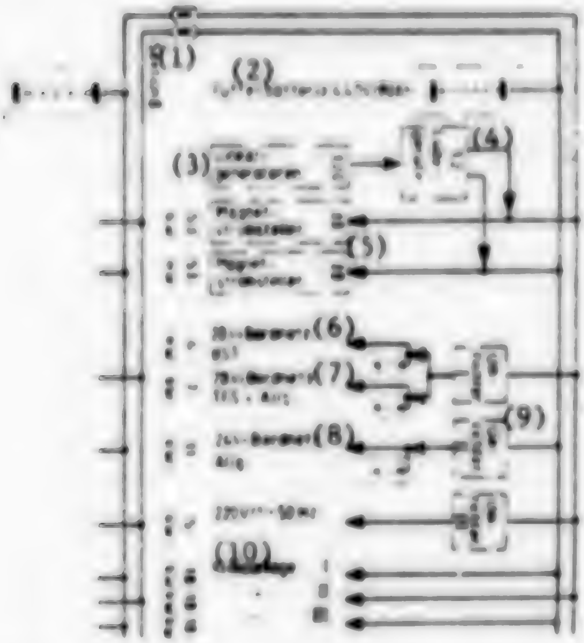

Figure 15. Principles of the on-board power supply of the TVE vehicle TR 06.

Key:
1. Section II
2. Buffer battery
3. Linear generators
4. Charging devices
5. Magnet-current control
6. 28 v = on-board power supply, on-board control system
7. 28 v = on-board power supply, carrier/guidance system + general
8. 24 v = on-board power supply, general
9. Inverter
10. Air conditioning equipment

These spring-supported slide runners are located in the upper longitudinal carriers of the suspension undercarriage and operate on the milled sliding surfaces of the roadway tracks. The guiding slide runners are identical with the mechanical braking runners which operate laterally on the guide rails. The lateral runners are suspended opposite to the floating undercarriage for brake operation. They are hydraulically fixed for their guiding function in the event of a controlled letdown.

The mechanical brake which intervenes only in the event of a failure of the propulsive energy supply and serves as a parking brake in the area of the railway station consists, in the interest of safety, of eight independent brake systems (one per suspension undercarriage) and is so dimensioned that assuming failure of two systems and also the most unfavorable frictional values they will nevertheless be guaranteed a braking delay of at least 1 m/sec^2 while on the other hand the short-time brake delays operating on the roadway will be kept below 4 m/sec^2. The redundant on-board power supply and the structure of the mechanical brake design permit operation of the vehicle only with two coupled sections.

The slotted design of the track rails [i.e., carrying rails] gives rise during motion of the vehicle to a modulation of the magnetic carrying fields. By means of special windings in the poles of the carrying magnets it is possible for power to be transmitted inductively and without contact into the vehicle. The use velocity of the linear generator depends upon the magnitude of the load into which it is connected and lies between 90 and 144 km/hr (Figure 16).

5.3. Car Body

The car body is designed as a skeleton in aluminum welded construction into the fields of which specially developed sandwich plates have been riveted. Figure 17 shows a longitudinal view with the arrangement of the doors, a plan view showing the arrangement of the seating and standing areas as well as a cross section. The internal furnishing will be similar to that of an airplane and will take into account the safety criteria conventional today in the construction of vehicles. Table 2 and Figure 18 [sic] have given more detailed information regarding the internal furnishing of the vehicle TR 06.

Much of the development work was taken up by aerodynamic model testing in order to find favorable vehicle shapes and in order to determine the longitudinal, lateral and vertical forces acting on the different areas of the vehicle together with their resulting moments [10]. Figure 18 shows, for example, the pressure distribution over the bow section at the height of the car body floor at a side-slip angle of 18° resulting from a side wind.

The control and surveillance of all vehicular equipment required for safe driving operation (riding data acquisition, doors, carrying/guidance system, brakes, pneumatics, hydraulics, electrical on-board power supply, ventilation, heating, air conditioning, signal lighting and data transmission) as well as for the control and surveillance of the presented status data of propulsion are accomplished depending upon the direction of travel by one of the two driver panels which are each arranged in the bow of the sections.

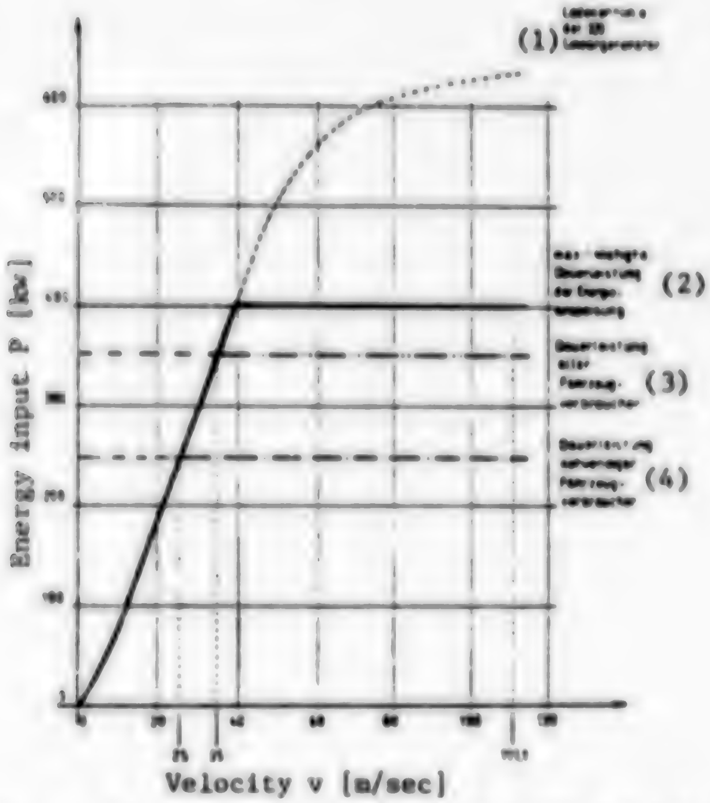

Figure 16. Energy supply for the TVE vehicle.

Key: 1. Charging characteristic of the 320 linear generator
2. Maximum required steady-state power energy supply
3. Steady-state power of all vehicular electrical loads
4. Steady-state power for essential vehicle loads

The vehicle is constructed on the basis of a closed safety design which also includes the cutaway locations to the roadway and to the propulsive system. Table 3 lists briefly the most important safety provisions which for lack of space it is not possible to examine here in detail.

6. Status of the Project

The construction of the TRANSRAPID test facility in Emsland is being carried out under a contract with the Federal Ministry of Research and Technology (BMFT) by the Transrapid Magnetic Railway Consortium which includes the firms AEG-Telefunken, Brown, Boveri and Cie AG, Cyckerhoff and Widmann

AG, Krauss-Maffei AG, Messerschmitt-Boelkow-Blohm GmbH, Siemens AG and Thyssen Industrie AG Henschel. As necessary in the case of projects of this order of magnitude the total project is subdivided into design, definition and development/production phases.

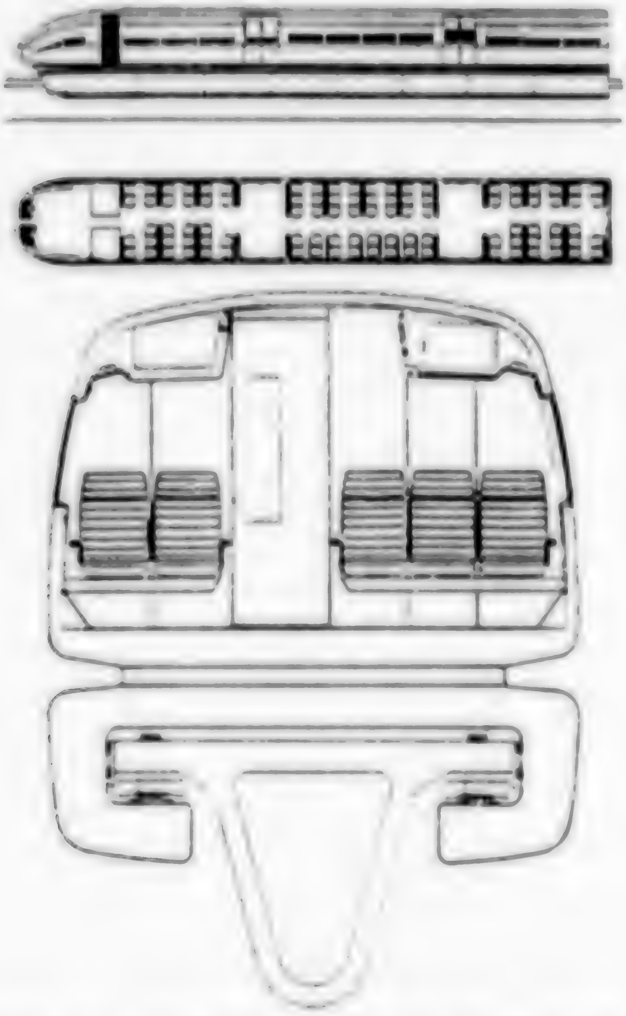

Figure 17. Car body of the TVE vehicle TR 06.

Table 2. Internal Furnishing of the TVE Vehicle TR 06

Internal finishing	Flame-resistant GFK panels
Partitions	Sandwich construction, emergency slides integrated
Windows	Two-pane bonded windows thermally insulated and mirror surfaced
Side doors	Four pneumatically actuated two-wing swivel-slide doors per section
Back wall door	Bolted back wall sliding door with position lock and with emergency passage

Table 2 (continued)

Internal doors	Two sliding compartment doors per section with self-actuated closing device
Chairs	Intercity-like comfort seating with flame-resistant upholstery
Floor covering	Heavy-duty nap covering of flame-resistant material
Baggage compartment	With removable GFK finishing and integrated side illumination
Air conditioning	Integrated into the car body floor; air exit in the window panels
Conductor's position	GFK-finished operating desk designed on ergonometric principles
Toolboxes	Housed in shock- and fire-protected rapidly accessible spaces
Cabling	In separate continuous fire-protected cable conduits having high-quality flame-resistant insulation
Illumination	Continuous central strip and integrated lateral illumination in the baggage compartment

Since the middle of 1979 the project has been in its production phase. Visible evidence of this is the construction road along the railroad route which has been extensively completed and also the field factory for manufacturing the suspension structure; erection of the latter will be completed by the middle of 1980. In addition, a number of requests for submission of proposals for systems and subsystems have now been concluded and contracts given out. For essentially new system components the design and manufacturing work is in progress. According to current planning around 20 km of route length (the straight route and the north loop) should be available in 1982 and on this segment the TR 06 will then start running.

Table 3. Safety Design of the TVE Vehicle TR 06

Design of the controlled setdown
Safety brakes
   LS [expansion unknown] brake/propulsion
   Mechanical brake
   Slide runners
Dimensioning with reference to partial function interruptions
Dimensioning with reference to sliding
Prevention of inadmissible forces or accelerations in the x direction ($b_x < 3.5$ m/sec^2)
Reliable propulsion shutdown capability
Out-of-step surveillance and shutdown of the LS, redundant design of safety-relevant circuits of the
   Energy supply
   Control
   Surveillance

Table 3 (continued)

Use of noninflammable and flame-resistant materials
Emergency slides for vehicle evacuation

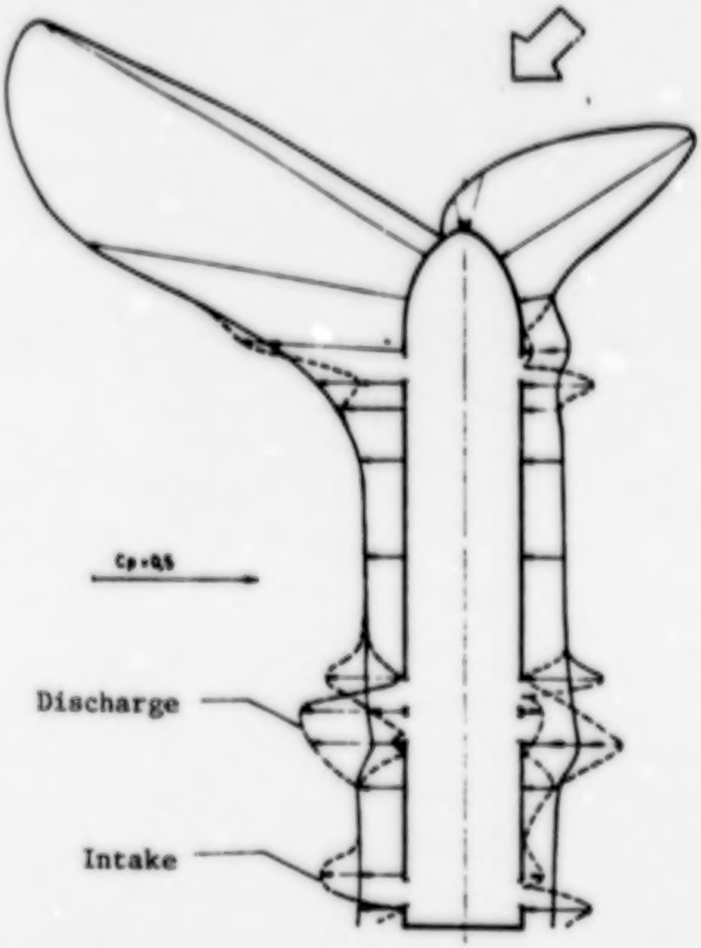

Figure 18. Transrapid 06, pressure distribution over the bow section. Side-slip angle 18°, effect of cool air intake and discharge.

We wish to mention the close cooperation among developers, certifying experts and licensing officials. This cooperation has extended over the entire course of the project and aims at assuring not only a test operation which can be approved without encountering any serious problems but also over and above this aims, insofar as this is possible for transport involving new guidance technique, at securing a test facility which will meet the requirements of licensing procedures in the future.--A 842

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